REDUCTION OF ELECTROSTATIC CHARGE ON A SUBSTRATE DURING PECVD PROCESS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to the fields of semiconductor manufacturing and chemical vapor deposition processes. More specifically, the present invention relates to a method of reducing the electrostatic charge on a substrate during a PECVD process.

Description of the Related Art

Plasma enhanced chemical vapor deposition (PECVD) of thin films uses plasma energy to create and sustain the chemical vapor deposition reaction. A radio-frequency (RF) induced plasma

source ignites a plasma and creates a plasma field in the deposition gas. The increase in deposition energy enables thin films to deposit at low temperatures and low pressures, thus realizing good film uniformity and throughput.

A PECVD application is performed in a vacuum chamber with a gas distribution means as a top electrode and a substrate support means as a bottom electrode in parallel. These conducting plates are typically several inches apart; the gap is variable to optimize process conditions. Additionally, a radio-frequency power supply is used to supply electrical power between the electrodes to ignite the plasma. A modern reactor is typically a multichamber cluster tool. PECVD is used to deposit thin films onto a substrate that includes, *inter alia*, flat panel displays, and glass or ceramic plates or disks.

A substrate is supported by a susceptor in the vacuum chamber. The susceptor is a mechanical part of the chamber and functions as a ground or bottom electrode during PECVD processing. Generally, the susceptor has a substrate support plate that is attached to a susceptor shaft and a lift assembly to raise and lower the substrate inside the process chamber.

The substrate is typically an oxide-based material such as glass, quartz, and the susceptor material is an aluminum-based material whose surface is anodized. As an electrostatic charge is built up between two insulators, it is also generated and built up on the backside of a substrate and the top susceptor surface. Thus, during the plasma enhanced chemical vapor deposition of a

thin film, both the substrate and the susceptor surface act as insulators.

The electrostatic charge generated during deposition of the film between the substrate and the susceptor surface holds the substrate to the susceptor surface. This charge must be dissipated or removed prior to lifting the substrate from the susceptor surface. Additional steps such as a power lift are used to remove the electrostatic charge. If the electrostatic charge is not properly dissipated prior to separating the substrate from the susceptor surface for unloading, the electrostatic charge can induce substrate breakage when the susceptor moves down. The power lift steps consist of a few steps of gas plasma such as hydrogen that does not affect the deposited film.

The plasma of the inactive gas used for the power lift causes the electrostatic charge on the susceptor support plate and the substrate body to redistribute, thereby limiting the electrostatic attraction between the substrate and the susceptor. Thus, sticking of the substrate to the susceptor support surface is reduced and the substrate is more easily separated from the susceptor support plate. Although this step minimizes losses due to substrate damage, each power lift application requires 15-20 seconds of processing time for each substrate. This additional processing time causes a significant reduction in throughput efficiency and concomitant loss of revenue.

Therefore, the prior art is deficient in the lack of effective means of reducing static charge on a substrate during

film deposition. Specifically, the prior art is deficient in the lack of an effective means of using a conductive susceptor to reduce static charge on a substrate. The present invention fulfills these long-standing needs and desires in the art.

SUMMARY OF THE INVENTION

In one embodiment of the present invention there is provided a method of reducing an electrostatic charge on a substrate during a plasma enhanced chemical vapor deposition process, comprising the step of depositing a conductive layer onto a top surface of a susceptor support plate disposed within a deposition chamber wherein the conductive layer dissipates the electrostatic charge on the bottom surface of the substrate during a plasma enhanced chemical vapor deposition process.

In another embodiment of the present invention there is provided a method of reducing an electrostatic charge on an oxide-based substrate during a plasma enhanced chemical vapor deposition process, comprising the steps of introducing silane into the deposition chamber; introducing from about 0.5% to about 1.0% phosphine in hydrogen gas into the deposition chamber; igniting the gases with an RF power of about 300W to about 900W at a pressure of about 0.3 Torr to about 10 Torr; and depositing a phosphine-doped amorphous silicon conductive layer or a phosphine-doped microcrystal silicon conductive layer onto a top surface of a susceptor support plate; where the phosphine-doped

amorphous silicon conductive layer or the phosphine-doped microcrystal silicon conductive layer dissipates the electrostatic charge on the bottom surface of the oxide-based substrate during a plasma enhanced chemical vapor deposition process.

In yet another embodiment of the present invention there is provided a method of depositing a film of material upon a substrate during a plasma enhanced chemical vapor deposition process comprising the steps of introducing a silicon-containing gas into the deposition chamber; igniting the gas under conditions such that a plasma is formed in the deposition chamber; depositing an amorphous silicon conductive layer or a microcrystal silicon conductive layer onto a top surface of a susceptor support plate; positioning the substrate on the amorphous silicon conductive layer or on the microcrystal silicon conductive layer such that an electrostatic charge on the bottom surface of the substrate induced during a subsequent plasma enhanced chemical vapor deposition process is dissipated through the amorphous silicon conductive layer or through the microcrystal silicon conductive layer; and subjecting the top surface of the substrate to a plasma enhanced chemical vapor deposition process thereby depositing the film of material onto the substrate.

In yet another embodiment of the present invention there is provided a method of depositing a film of material upon an oxide-based substrate during a plasma enhanced chemical vapor deposition process comprising the steps of introducing silane into the deposition chamber; introducing from about 0.5% to about 1% phosphine in hydrogen gas into the deposition chamber;

igniting the gases with an RF power of about 300W to about 900W at a pressure of about 0.3 Torr to about 10 Torr; depositing a phosphine-doped amorphous silicon conductive layer or a phosphine-doped microcrystal silicon conductive layer onto a top surface of a susceptor support plate; positioning the oxide-based substrate on the phosphine-doped amorphous silicon conductive layer or on the phosphine-doped microcrystal silicon conductive layer such that an electrostatic charge on the bottom surface of the oxide-based substrate induced during subsequent plasma enhanced chemical vapor deposition is dissipated through the phosphine-doped amorphous silicon conductive layer or through the phosphine-doped microcrystal silicon conductive layer; and subjecting the top surface of the oxide-based substrate to a plasma enhanced chemical vapor deposition process thereby depositing the film of material onto the oxide-based substrate.

In yet another embodiment of the present invention there is provided a conductive susceptor for use in a deposition chamber for depositing a film of material onto a substrate during a plasma enhanced chemical vapor deposition process, the susceptor comprising a support plate mounted on a shaft, the support plate having an upper surface adapted to support a substrate wherein the upper surface has a conductive material disposed thereon and a lower surface connected to the shaft and interfacing with the shaft.

Other and further aspects, features, and advantages of the present invention will be apparent from the following

description of the embodiments of the invention given for the purpose of disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the matter in which the above-recited features, advantages and objects of the invention, as well as others which will become clear, are attained and can be understood in detail, more particular descriptions of the invention briefly summarized above may be had by reference to certain embodiments thereof which are illustrated in the appended drawings. These drawings form a part of the specification. It is to be noted, however, that the appended drawings illustrate embodiments of the invention and therefore are not to be considered limiting in their scope.

Figure 1 depicts schematically how a static charge builds up between a substrate and a susceptor during PECVD (**Fig. 1A**) and how the presence of a conductive layer between a substrate and the susceptor reduces static charge between the substrate and the susceptor during PECVD (**Fig. 1B**).

Figure 2 depicts a cross-sectional schematic representation of the susceptor with a conductive layer deposited thereon.

DETAILED DESCRIPTION OF THE INVENTION

In one embodiment, the present invention is directed a method of reducing an electrostatic charge on a substrate during a plasma enhanced chemical vapor deposition process, comprising the step of depositing a conductive layer onto a top surface of a susceptor support plate disposed within a deposition chamber wherein the conductive layer dissipates the electrostatic charge on the bottom surface of the substrate during a plasma enhanced chemical vapor deposition process. In this embodiment the substrate may be an insulative, non-metal material such as an oxide-based substrate or a plastic. Representative examples of the oxide-based substrate include glass, quartz or a ceramic material.

In one aspect of this embodiment there is provided a method of depositing the conductive layer onto the top surface of the susceptor support plate comprises the steps of introducing a silicon-containing gas into the deposition chamber; and igniting the gas under conditions such that an amorphous silicon conductive layer or a micrcrystal silicon conductive layer is deposited onto the top surface of the susceptor support plate. This aspect of this embodiment may further comprise the step of introducing a mixture of phosphine and hydrogen gas into the deposition chamber such that a phosphine-doped amorphous silicon conductive layer or a phosphine-doped microcrystal silicon conductive layer is deposited.

A representative examples of the silicon-containing gas are silane, disilane, methylsilane and trimethylsilane and the

phosphine/hydrogen gas mixture may comprise about 0.5% to about 1% phosphine in hydrogen mixture. The plasma may be ignited using a RF power of about 300 W to about 900 W. A representative range is from about 300 W to about 400 W; alternatively, the RF power may be about 900 W. Chamber pressure may be from about 0.3 Torr to about 10 Torr with a representative example of chamber pressure being about 1.3 Torr.

In another aspect of this embodiment there is provided a method of depositing the conductive layer onto the top surface of the susceptor support plate comprising the steps of introducing silane into the deposition chamber; introducing from about 0.5% to about 1% phosphine in hydrogen gas into the deposition chamber; and igniting the gases with an RF power of about 300W to about 900W at a pressure of about 0.3 Torr to about 10 Torr such that a phosphine-doped amorphous silicon conductive layer or a phosphine-doped microcrystal silicon layer is deposited onto the top surface of the susceptor support plate.

In another embodiment of the present invention there is provided a method of reducing an electrostatic charge on an oxide-based substrate during a plasma enhanced chemical vapor deposition process, comprising the steps of introducing silane into the deposition chamber; introducing from about 0.5% to about 1.0% phosphine in hydrogen gas into the deposition chamber; igniting the gases with an RF power of about 300W to about 900W at a pressure of about 0.3 Torr to about 10 Torr; and depositing a phosphine-doped amorphous silicon conductive layer or a phosphine-doped microcrystal silicon conductive layer onto a top

surface of a susceptor support plate; where the phosphine-doped amorphous silicon conductive layer or the phosphine-doped microcrystal silicon conductive layer dissipates the electrostatic charge on the bottom surface of the oxide-based substrate during a plasma enhanced chemical vapor deposition process. In this embodiment the oxide-based substrate may be glass, quartz or ceramic.

In yet another embodiment of the present invention there is provided a method of depositing a film of material upon a substrate during a plasma enhanced chemical vapor deposition process comprising the steps of introducing a silicon-containing gas into the deposition chamber; igniting the gas under conditions such that a plasma is formed in the deposition chamber; depositing an amorphous silicon conductive layer or a microcrystal silicon conductive layer onto a top surface of a susceptor support plate; positioning the substrate on the amorphous silicon conductive layer or on the microcrystal silicon conductive layer such that an electrostatic charge on the bottom surface of the substrate induced during a subsequent plasma enhanced chemical vapor deposition process is dissipated through the amorphous silicon conductive layer or through the microcrystal silicon conductive layer; and subjecting the top surface of the substrate to a plasma enhanced chemical vapor deposition process thereby depositing the film of material onto the substrate. In an aspect of this embodiment, a phosphine/hydrogen mixture may be introduced into the deposition chamber as described in detail *supra*. The substrates, processing gases and deposition conditions are as described *supra*.

In yet another embodiment of the present invention there is provided method of depositing a film of material upon an oxide-based substrate during a plasma enhanced chemical vapor deposition process comprising the steps of introducing silane into the deposition chamber; introducing from about 0.5% to about 1.0% phosphine in hydrogen gas into the deposition chamber; igniting the gases with an RF power of about 300W to about 900W at a pressure of about 0.3 Torr to about 10 Torr; depositing a phosphine-doped amorphous silicon conductive layer or a phosphine-doped microcrystal silicon conductive layer onto a top surface of a susceptor support plate; positioning the oxide-based substrate on the phosphine-doped amorphous silicon conductive layer or on the phosphine-doped microcrystal silicon conductive layer such that an electrostatic charge on the bottom surface of the oxide-based substrate induced during subsequent plasma enhanced chemical vapor deposition is dissipated through the phosphine-doped amorphous silicon conductive layer or through the phosphine-doped microcrystal silicon conductive layer; and subjecting the top surface of the oxide-based substrate to a plasma enhanced chemical vapor deposition process thereby depositing the film of material onto the oxide-based substrate. Examples of the oxide-based substrate are glass, quartz or a ceramic material.

In yet another embodiment of the present invention there is provided a conductive susceptor for use in a deposition chamber for depositing a film of material onto a substrate during a plasma enhanced chemical vapor deposition process, the

susceptor comprising a support plate mounted on a shaft, the support plate having an upper surface adapted to support a substrate wherein the upper surface has a conductive material disposed thereon and a lower surface connected to the shaft and interfacing with the shaft. The conductive material is a conductive layer and comprises those materials as disclosed *supra*. The substrates are those as disclosed *supra*.

Provided herein is a method of reducing the electrostatic charge on a substrate during PECVD of a thin film. Because the susceptor support plate and the substrate comprise insulation materials, an electrostatic charge builds up between the top susceptor surface and the bottom surface of the substrate upon which the film is being deposited during a PECVD process (Figure 1A). There is an induced negative charge on the top surface of the susceptor support plate. Placement of the substrate upon the support plate surface does not completely electrically screen the top surface from the plasma. The net positive charge of the plasma during PECVD deposition of a thin film induces a negative charge on the top surface of the substrate causing the bottom surface of the substrate to carry a positive charge and, therefore, the top surface of the susceptor support plate must carry a negative charge. As stated, the substrate and susceptor are insulators, the electrostatic charge formed between the surface of the support plate and the bottom surface of the substrate builds up without dissipation.

Deposition of a conductive layer onto the top surface of the susceptor support plate prior to depositing a thin film during a

PECVD process dissipates the accumulated electrostatic charge between the substrate and susceptor support plate (Figure 1B). During a PECVD process the potential of the susceptor is held to ground. Thus, a conductive layer over the top surface of the susceptor support plate would dissipate the induced negative charge normally accumulated on the top surface of the support plate through itself and so reduce any electrostatic charge buildup on the bottom surface of the substrate.

Figure 2 shows a susceptor **135** as disclosed herein. The susceptor comprises a support plate **20** mounted on a susceptor shaft **137** containing a hollow core (not shown) and operably attached there to. The susceptor **135** is centrally disposed within a deposition chamber (not shown). The susceptor support plate **20** may include a top plate, a base plate and a braised region disposed there between; additionally, the susceptor support plate may contain heaters disposed between the top plate and the base plate (not shown).

Lift pins **171** move upwards and downwards through lift pin holes **161** to contact and support the substrate **165** for positioning onto and subsequent lifting off of the support plate **20**. A robot blade (not shown) facilitates the transfer of the substrate **165** into and out of the deposition chamber. The movement of the lift pins **171** through the lift pin holes **161** are controlled by a controller **177** which operates known mechanisms **180** such as translation mechanisms or linear feed throughs.

The depth "d" of the support plate **20** is typically about one inch which can accommodate a substrate up to about 1000mm x 1200 mm. The length "l" and, therefore, the size of the support plate **20** can be adjusted to accommodate either large or small substrates. The susceptor support plate has a top surface **176** that comprises anodized aluminum with a conductive layer **22** disposed thereon.

The substrate **165** is placed into contact with the lift pins **171** by the robot blade which is subsequently withdrawn. The substrate is lowered until contacting the upper surface **23** of the conductive layer **22** for processing. The substrate **165** is shown herein supported off the top surface **23** of the conductive layer to better view the induced charge distribution on the substrate **165** and the conductive layer **22**.

Deposition process gases are introduced into the deposition chamber through a gas distribution face plate **122**. An RF power **172** is provided to ignite a plasma **169** within the process gases. The gas distribution plate **122** serves as a cathode and the susceptor **135** is held to ground. The primarily positive charge of the plasma **169** induces a negative charge on the top surface **175** of the substrate **165**. Thus, the bottom surface **173** of the substrate becomes positively charged and the top surface **23** of the conductive layer **22** becomes negatively charged. In the absence of the conductive layer **22**, the anodized surface **176** of the support plate **20** has insulation properties and an electrostatic charge would accumulate on the bottom surface **173** of the

substrate **165**. In the method described herein, the conductive layer **22** dissipates the accumulated electrostatic charge.

The substrate may be any insulative non-metallic material such as an oxide-based material or a plastic. For example, the oxide-based substrate may be glass, quartz or a ceramic material. Substrates may be any size ranging from, for example, 370mm x 470mm to 1000mm x 1200mm. The susceptor material is an aluminum-based material with an anodized surface. The conductive layer may comprise amorphous or microcrystal silicon or impurity-doped amorphous or microcrystal silicon such as phosphine-doped amorphous or microcrystal silicon. Precursor gases used to deposit the conductive layer may be silane (SiH_4), disilane, methylsilane or trimethylsiland and phosphine PH_3 or a mixture of gases such phosphine in silane or phosphine in hydrogen. It is also contemplated that the silicon conductive layer may be boron-doped. Such boron precursor gases could comprised diborane (B2H6) or diborane in hydrogen.

It is further contemplated that this method of reducing electrostatic charge on the substrate will further enhance throughput. If a conductive layer is deposited upon the susceptor, then the power lift can be removed from CVD processing and total processing time can be reduced about 15-20 sec per substrate. Additionally, eliminating the power lift plasma after film deposition reduces plasma damage on the film and the device patterns. A shorter processing time improves throughput of CVD system and reduces cost of ownership in the production line.

The following examples are given for the purpose of illustrating various embodiments of the invention and are not meant to limit the present invention in any fashion.

EXAMPLE 1

Deposition of conductive layer

The conductive layer is deposited upon the anodized susceptor support surface prior to placement of the substrate upon the support surface. For example, a phosphine-doped amorphous silicon layer or a phosphine-doped microcrystal silicon layer may be deposited by PECVD using silane and phosphine. Silane gas and 0.5% phosphine in hydrogen gas are flowed into the deposition chamber. The chamber pressure is low at about 1.3 Torr and the deposition temperature may be any temperature.

Thus the impurity-doped amorphous silicon may be deposited on the susceptor support surface at temperatures similar to those used for subsequent PECVD deposition of the film onto the substrate. Deposition time is about 30 seconds and yields a conductive layer of ~300-1000 Å thick; the precursor gases flow rates and the RF power used to generate a plasma is dependent on the area of the susceptor support plate. A boron-doped amorphous silicon layer may be deposited upon the support plate under similar conditions

Table 1 lists process conditions for deposition of a phosphine-doped amorphous silicon layer onto a susceptor support surface sized to stabilize a 370mm x 470 substrate and a 1000mm x 1200mm substrate.

TABLE 1

Process conditions for conductive layer deposition

	370mm x 470mm	1000mm x 1200mm
Precursor gas		
SiH_4	500 sccm	1200 sccm
PH_3	5 sccm	23 sccm
H_2	995 sccm	4577 sccm
Carrier gas		
H_2	500 sccm	2300 sccm
Pressure	1.3 Torr	1.3 Torr
Spacing	1500 mils	1500 mils
Temperature	any temp.	any temp.
RF Power	~300-400 W	~900 W
Deposition Time	30 secs.	30 secs.
Thickness	~300-1000 Å	~300-1000 Å

It is to be noted that these process conditions are not limiting. For example, phoshine may comprise from about 0.5% to about 1.0% in hydrogen for deposition. The chamber pressure may be from about 0.3 Torr to about 10 Torr. Any temperature may be used to deposit the conductive layer, however, those temperatures close to that required for the CVD process improve efficiency and throughput of the process.

EXAMPLE 2

Throughput improvement

The cost benefits from eliminating the power lift step in the PECVD deposition of thin films onto a substrate, particularly oxide-based substrates are significant. Table 2 shows the amount of throughput improvement by implementing this method for just one month for a 680mm x 880mm substrate of a LCD-TFT device.

TABLE 2

Throughput improvement

Application Film	Current Process Time	Current thrput (sub/hr)	Improved Process Time	Improved Thrput (sub/hr)	% Diff Improve
Single layer-	146 sec	67.3	131 sec	71.3	6%
Single layer-2	184 sec	57.7	169 sec	60.6	5%
Three layer-1	387 sec	30.3	372 sec	31.1	3%
Three layer-2	419 sec	24.4	400 sec	25.2	3%

This data indicates that the throughput can be improved about 3-6% depending on the application film. A 3% throughput improvement calculated as LCD-TFT product cost translates to roughly six million dollars additional revenue. For example, if it is fully utilized, a LCD-TFT fabrication line produces 70,000 substrates per month; this is the monthly capacity of the line. A 3% throughput improvement produces 2100 substrates/month more for a 680mm x 880mm substrate. Each substrate has six LCD panels; each panel's retail price is about \$450. Therefore, the total cost effect is about 2100 substrates x 6 panels x \$450, or 5.7 million dollars.

The following references or patents were cited herein:

1. Robert Robertson, Marc M. Kollrack, Angela T. Lee, Kam Law, and Dan Maydan. Method and Apparatus for Electrostatically maintaining Substrate Flatness. U.S. Patent No. 6,177,023B1 (Issued: January 23, 2001).

2. Robert Robertson, Marc M. Kollrack, Angela T. Lee, Kam Law, and Dan Maydan. Method of limiting sticking of body to susceptor in a deposition treatment. U.S. Patent No. 5,380,566 (Issued: January 10, 1995).

Any publications mentioned in this specification are indicative of the levels of those skilled in the art to which the invention pertains. These patents and publications are herein incorporated by reference to the same extent as if each individual publication was specifically and individually indicated to be incorporated by reference.

One skilled in the art will readily appreciate that the present invention is well adapted to carry out the objects and obtain the ends and advantages mentioned, as well as those inherent therein. It will be apparent to those skilled in the art that various modifications and variations can be made in practicing the present invention without departing from the spirit or scope of the invention. Changes therein and other uses will occur to those skilled in the art which are encompassed within the spirit of the invention as defined by the scope of the claims.